

Treatment of Delta Waters

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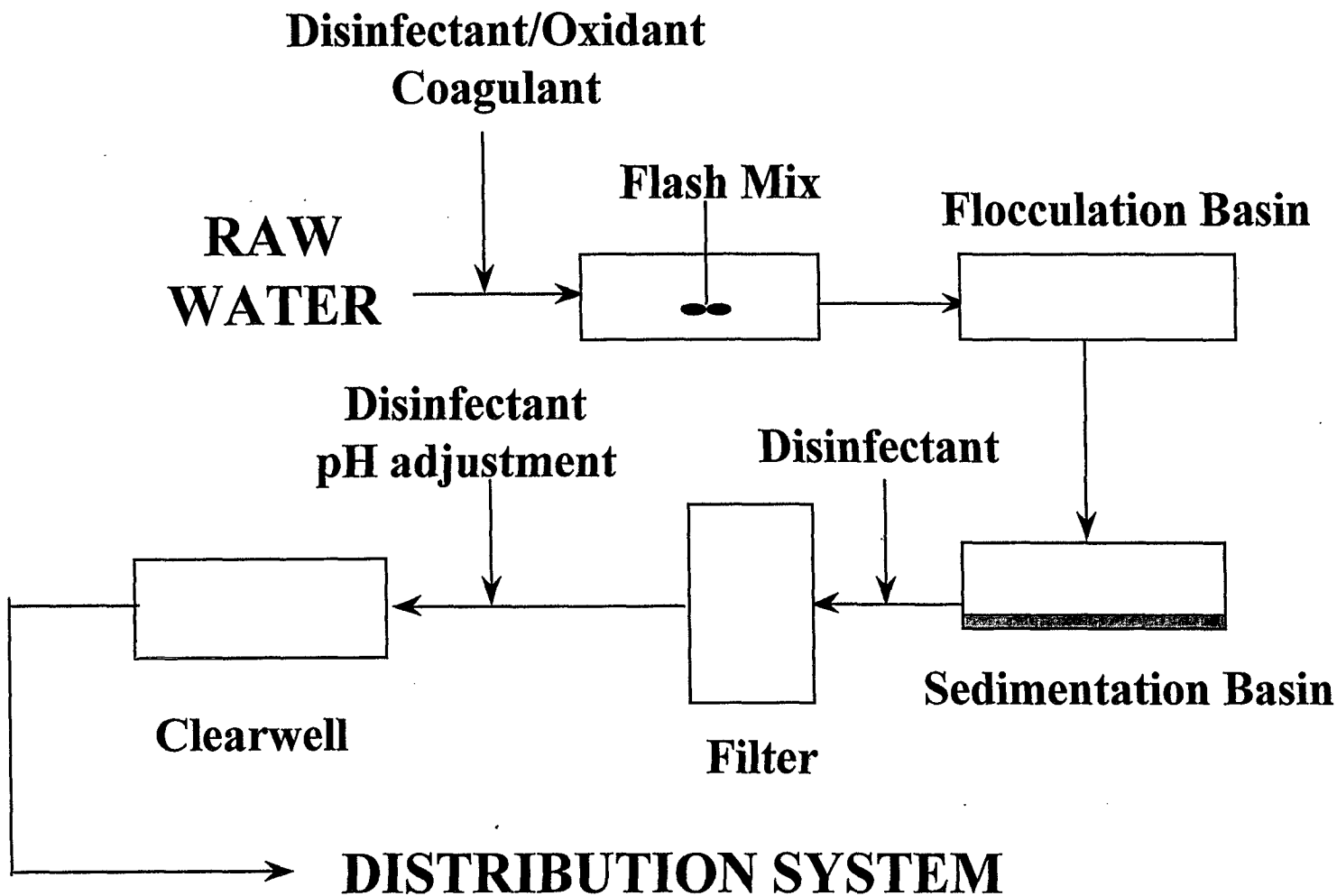
Treatment of Delta Waters

- What are the impacts of using different treatment methods on Delta water?
- What are the current and future regulations?
 - Disinfection By-Product (DBP) Rule
 - Enhanced Surface Water Treatment Rule (ESWTR)
- Can future regulations be met?

Current Treatment/ Disinfection Practices

D-036049

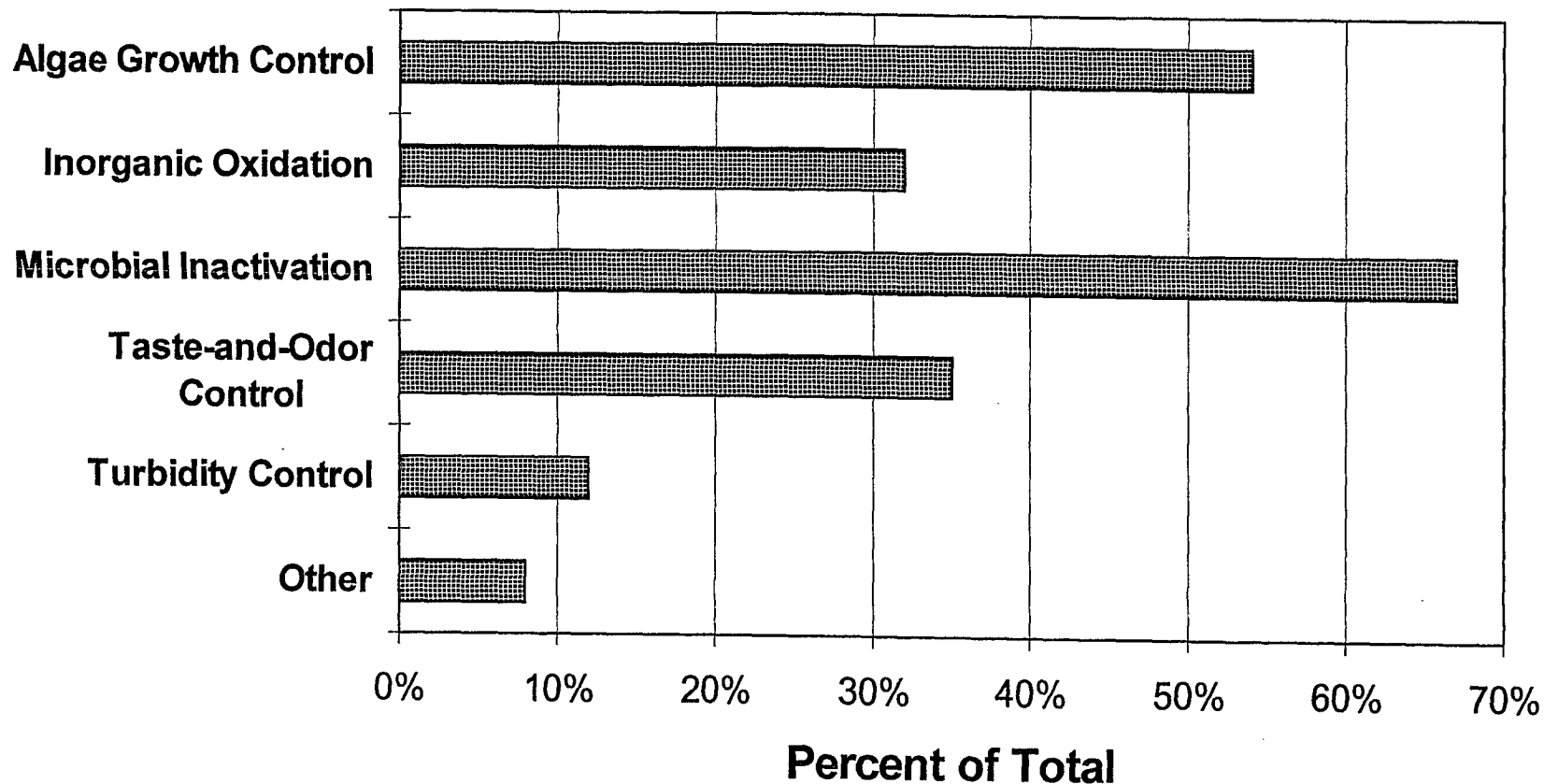
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Typical Conventional Water Treatment Plant Schematic

Drinking water systems use predisinfection/preoxidation to control a variety of water quality problems (e.g., iron and manganese, sulfides, zebra mussels, Asiatic clams, taste and odor).

**1997 Survey of 329 Large Surface Water Treatment
Plants: (Multiple) Reason(s) for Predisinfection**



Disinfectants Used in Drinking Water

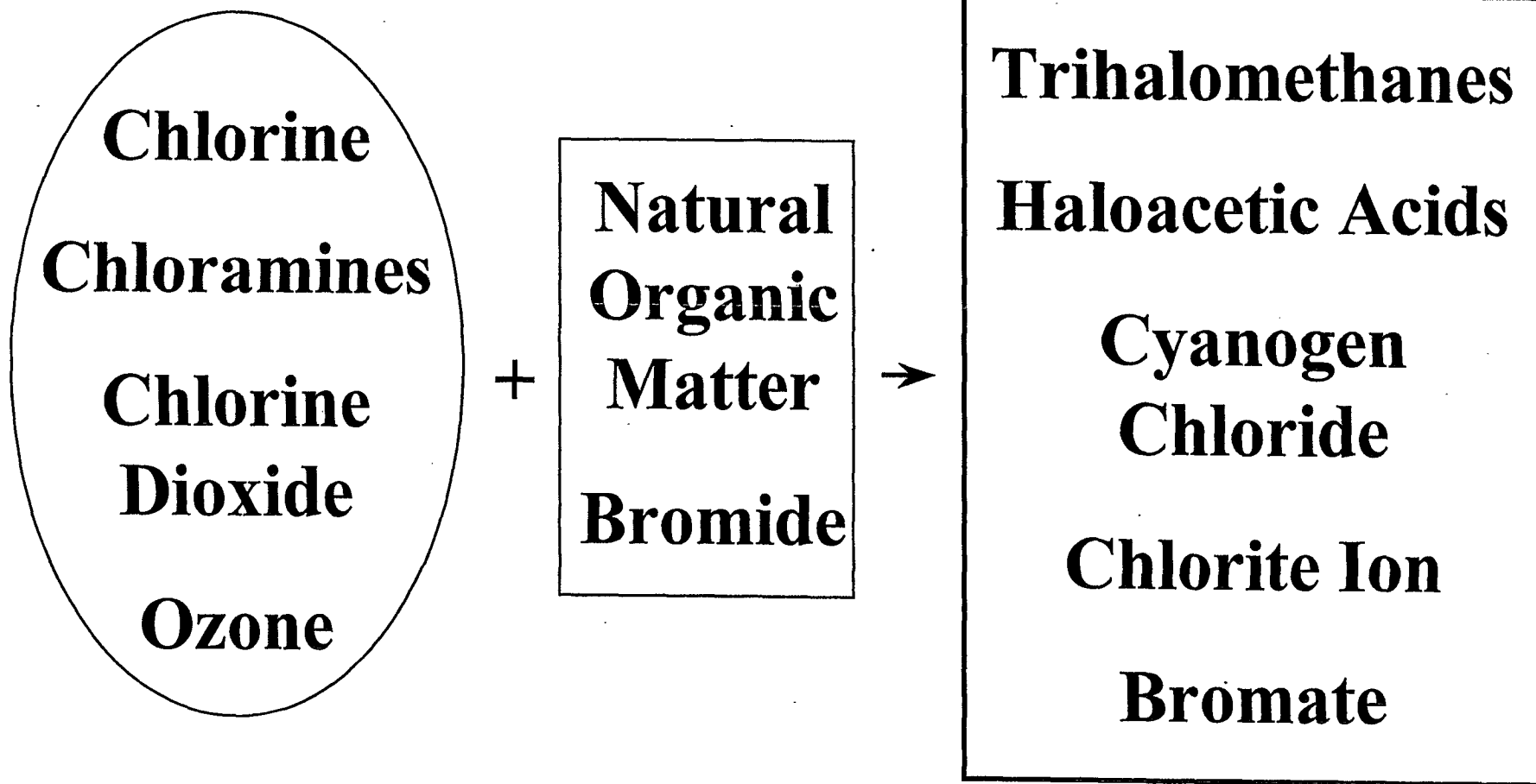
- **Chlorine:** Proven effectiveness, low capital and operating costs, extensive experience
- **Chloramines:** Compared to chlorine (1) produces less DBPs, (2) residual is longer lasting, (3) less effective microbial inactivation
- **Chlorine dioxide:** Effective disinfectant and oxidant, does not form trihalomethanes, principal by-product is chlorite ion
- **Ozone:** Highly reactive, very effective disinfectant and oxidant, produces oxidation by-products

Chemistry of DBP Formation

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Disinfectant + Precursor ---> DBPs
(impacted by water quality parameters)

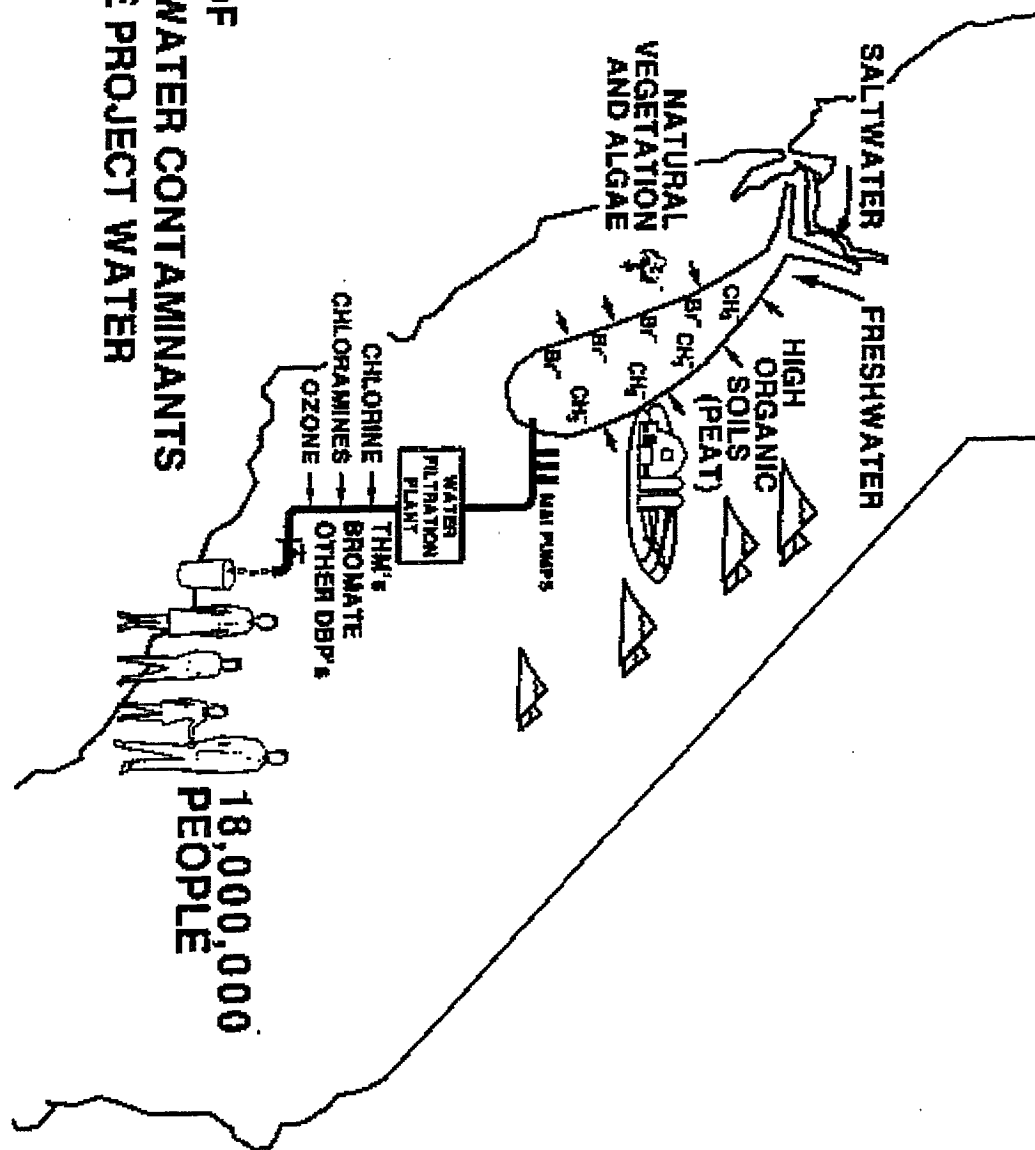


Natural Organic Matter

- **Sources: Decaying vegetation, peat soil, algae, etc.**
- **Surrogate parameter: Total organic carbon (TOC) measure of amount of natural organic matter in water**

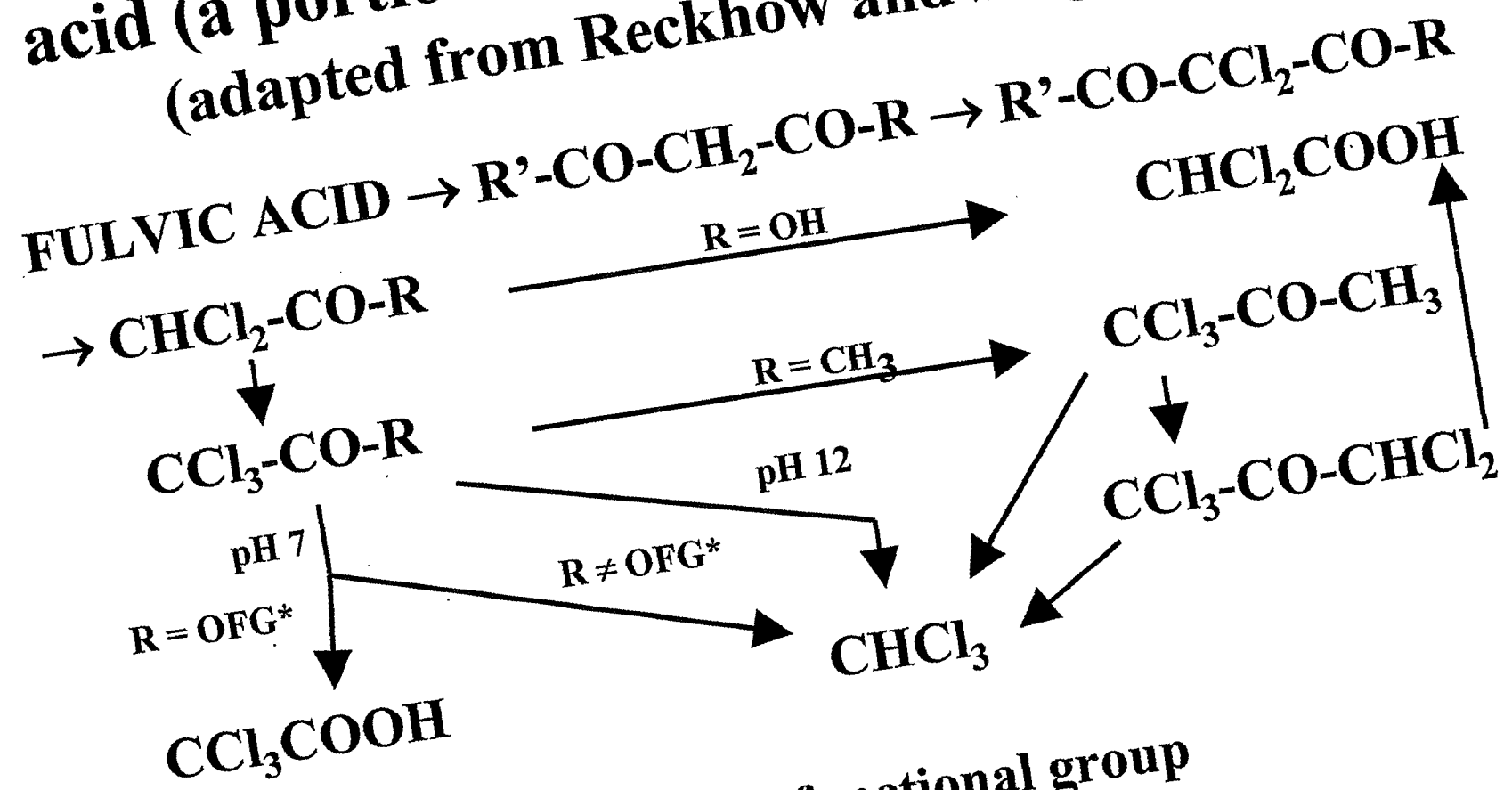
Bromide

- **Saltwater intrusion**
- **Geologically-trapped ancient seawater**
- **Oil-field brines**



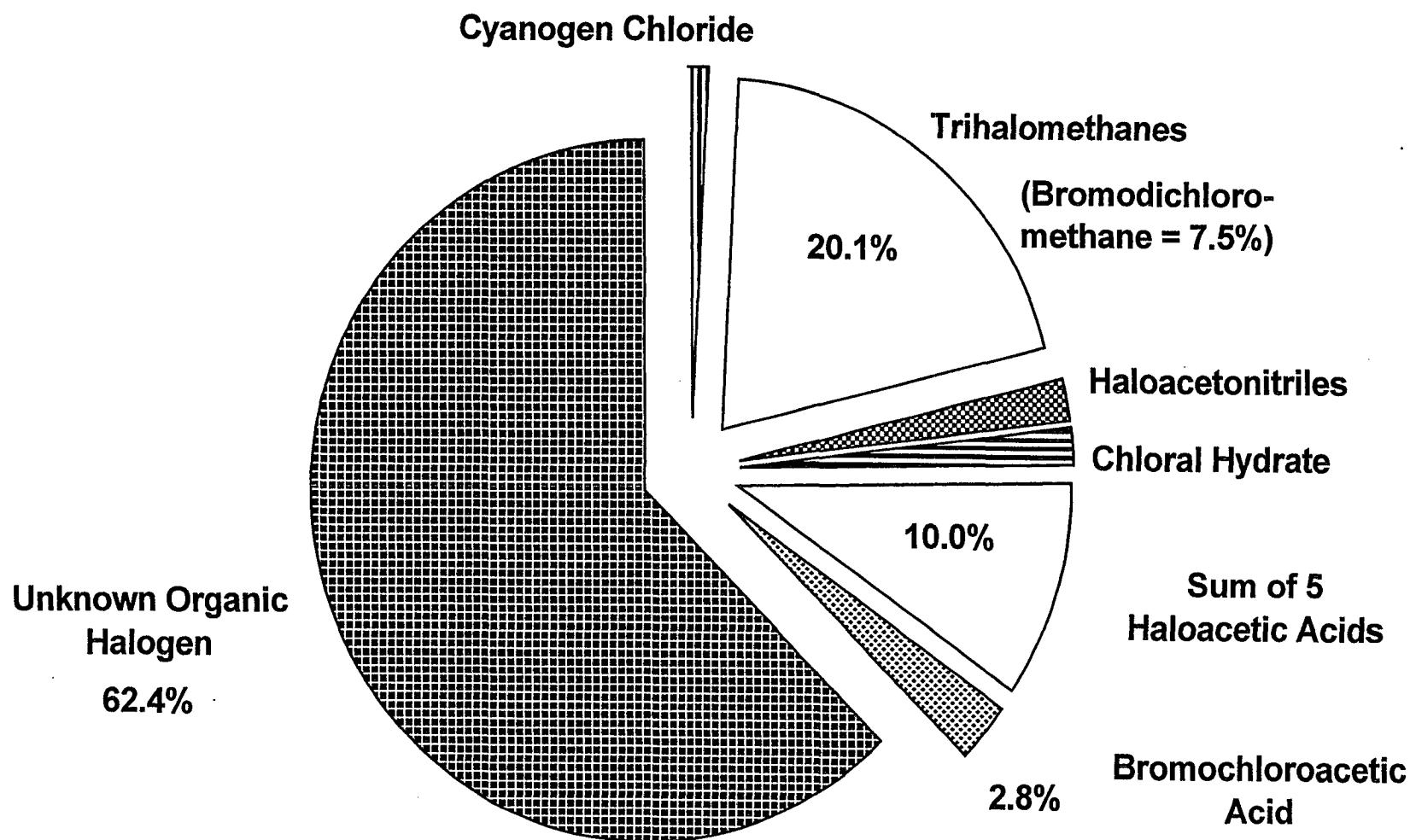
**ORIGIN OF
SOURCEWATER CONTAMINANTS
IN STATE PROJECT WATER**

**Generalized conceptual model for the formation
of major organic halide products from fulvic
acid (a portion of the natural organic matter)
(adapted from Reckhow and Singer, 1985)**



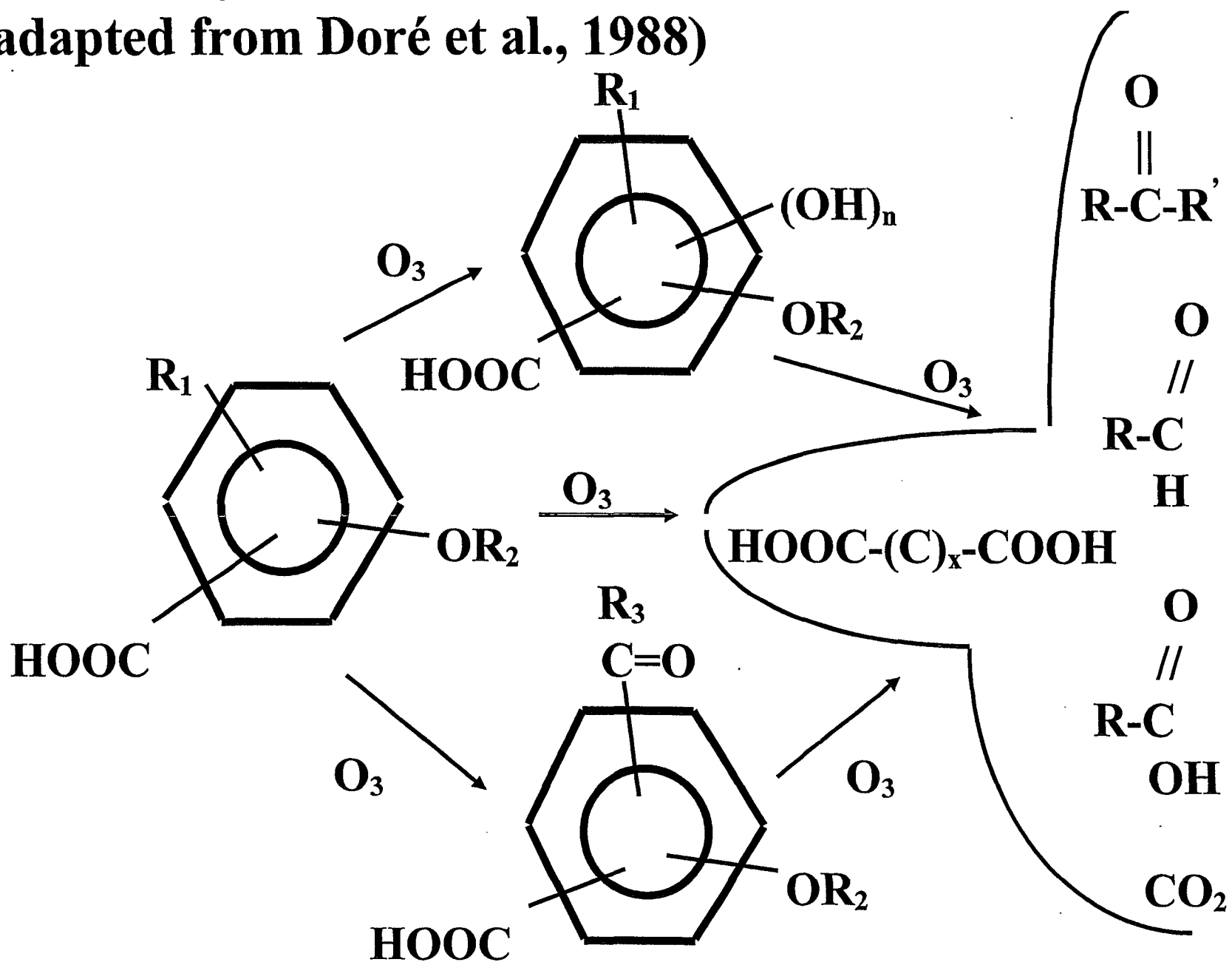
***Where OFG = oxidizable functional group**

**Percentage of Total Organic Halogen Accounted for by DBPs
in Information Collection Rule (on a Molar Basis)***



*Mills Plant (CA) finished water, August 1997
(Total organic halogen = 172 µg/L, raw-water bromide = 0.15 mg/L)

A summary of the action of ozone in DBP formation (adapted from Doré et al., 1988)

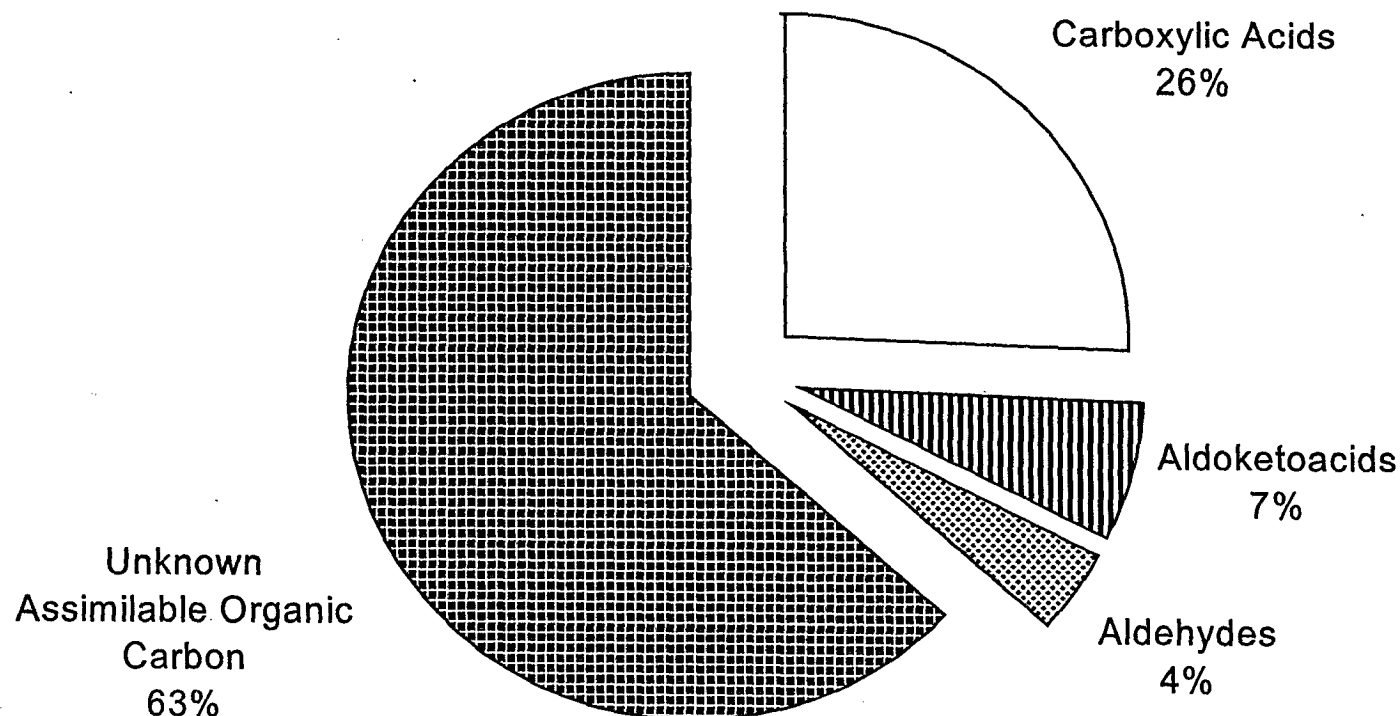


Formation of Biodegradable Organic Matter

(TOC = 2.2 mg/L, biodegradable organic carbon = 0.5 mg/L)

Relative Composition of Assimilable Organic Carbon (286 $\mu\text{g C/L}$)
in Filter Influent (Krasner et al., 1996)

[Assimilable Organic Carbon in Filter Effluent = 104-129 $\mu\text{g C/L}$]



Regulatory Background

Stage 1 DBP Rule

- Promulgated December 1998
 - Lowered maximum contaminant level (MCL) for trihalomethanes to 80 $\mu\text{g/L}$
 - Established MCL for sum of 5 haloacetic acids at 60 $\mu\text{g/L}$
 - Established MCLs for bromate at 10 $\mu\text{g/L}$ and for chlorite at 1 mg/L
 - Also requires removal of DBP precursors (i.e., TOC)

Required Removal of TOC by Enhanced Coagulation for Surface-Water Systems Using Conventional Treatment

Alkalinity, mg/L as CaCO_3

TOC (mg/L)	0-60	>60 - 120	>120
>2.0 – 4.0	35.0	25.0	15.0
>4.0 – 8.0	45.0	35.0	25.0
>8.0	50.0	40.0	30.0

Stage 2 DBP Rule

- Will be promulgated by May 2002
 - Currently being negotiated
 - Placeholder MCLs in 1994 proposed rule
 - 40 µg/L for trihalomethanes
 - 30 µg/L for haloacetic acids
 - 5 µg/L for bromate
 - To be promulgated with ESWTR
 - May include inactivation requirement for *Cryptosporidium*

Other Stage 2 DBP Rule Options

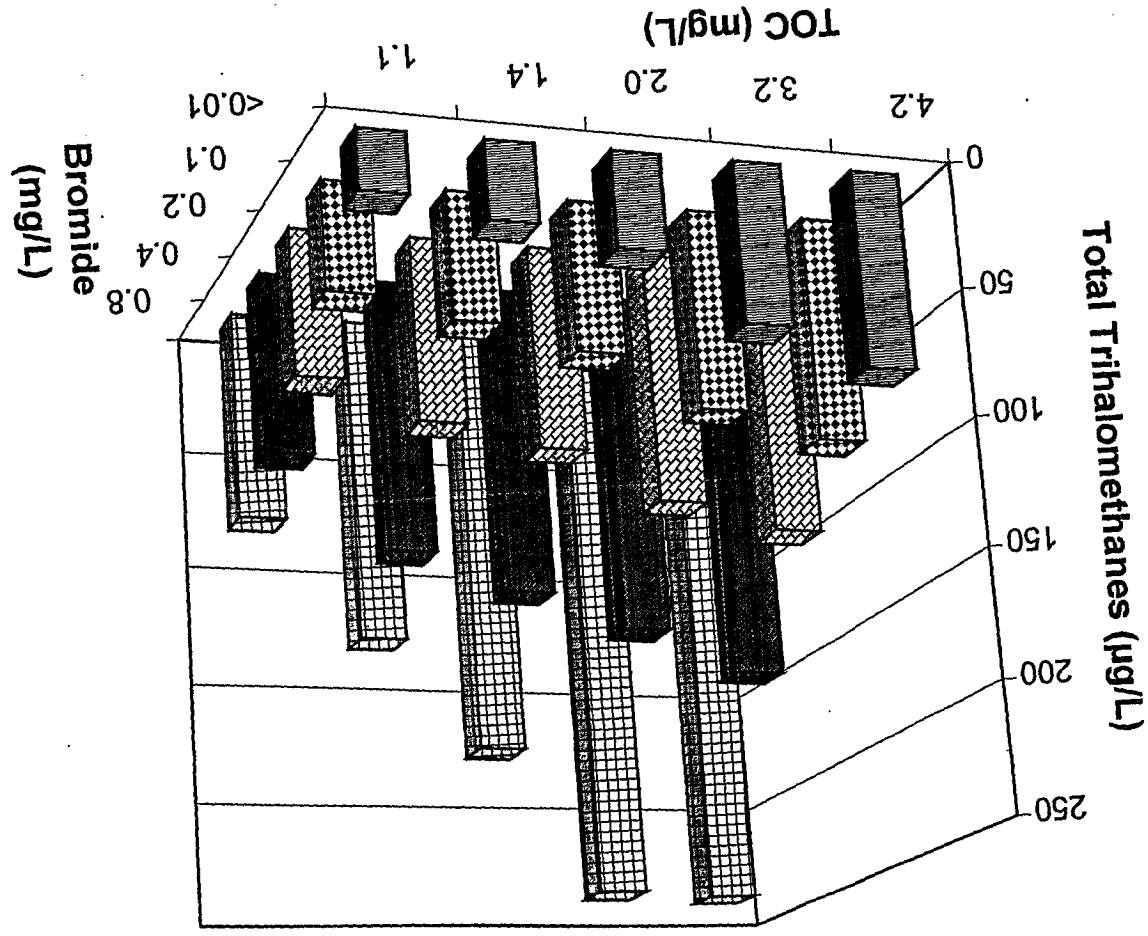
- Set MCLs for individual DBPs of health concern
 - Certain brominated DBPs (e.g., bromodichloromethane) (1) have higher cancer potencies and (2) have been associated with adverse reproductive/developmental health effects (e.g., spontaneous abortion)
- Eliminate aspects of the current compliance formula based on a running annual average

Effect of TOC (NOM) and Bromide on DBP Formation

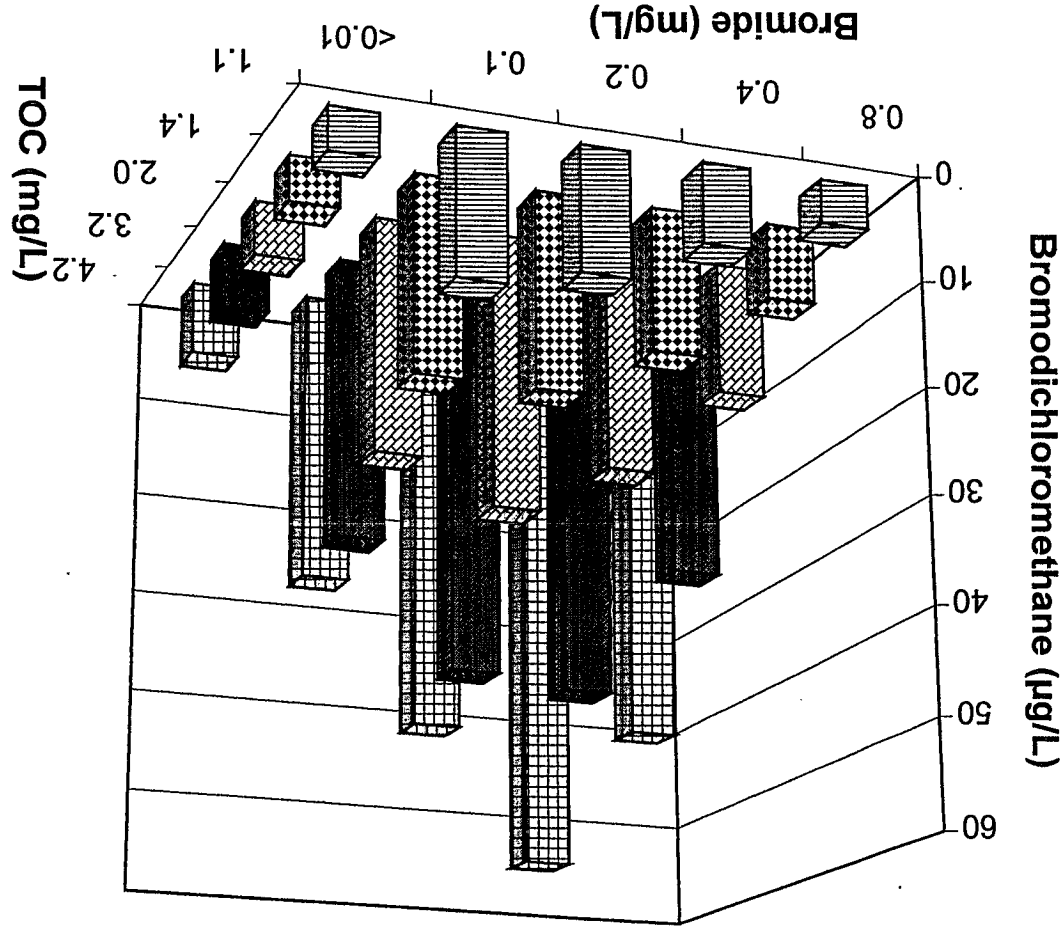
Effects of TOC (NOM) and Bromide on DBP Formation (Krasner et al., 1994; Najm & Krasner, 1995)

- Experimental approach
 - “Baseline” water = Sacramento River water upstream of the Delta
 - TOC = 1.1-1.2 mg/L, bromide <0.01 mg/L
 - Water spiked with 5 levels each of TOC and bromide (5 x 5 matrix: 25 unique waters)
 - TOC spike = agricultural drain (35 mg/L TOC)
 - TOC evaluated = 1.1 to 4.2 mg/L
 - Bromide evaluated = <0.01 to 0.8 mg/L

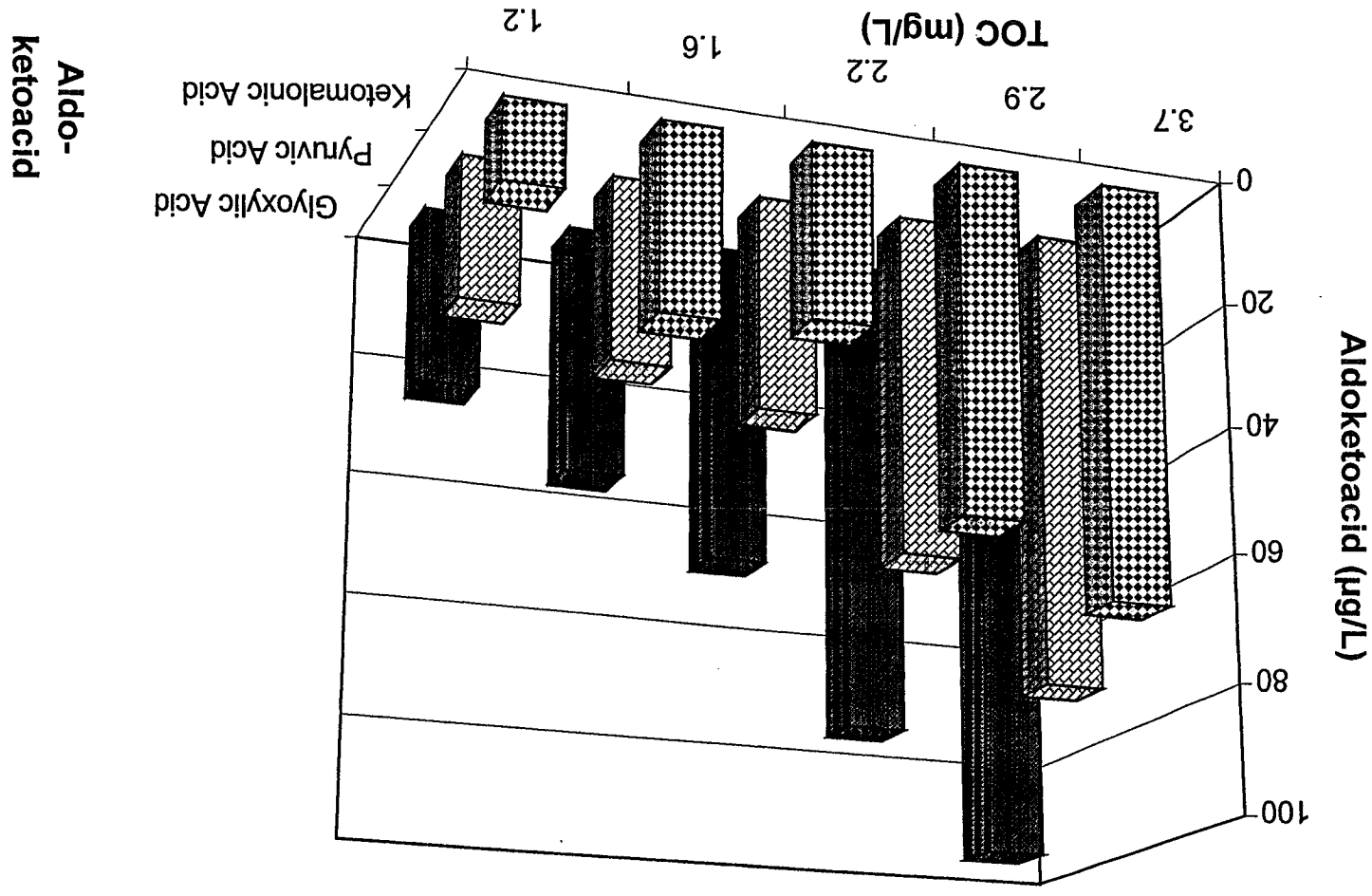
Effect of TOC and Bromide on the Formation of Total Trihalomethanes: Temperature = 25 C, pH = 8.2, Reaction Time = 3 hr
(Krasner et al., 1994)



Effect of TOC and Bromide on the Formation of Bromodichloromethane: Temperature = 25 C, pH = 8.2, Reaction Time = 3 hr (Krasner et al., 1994)

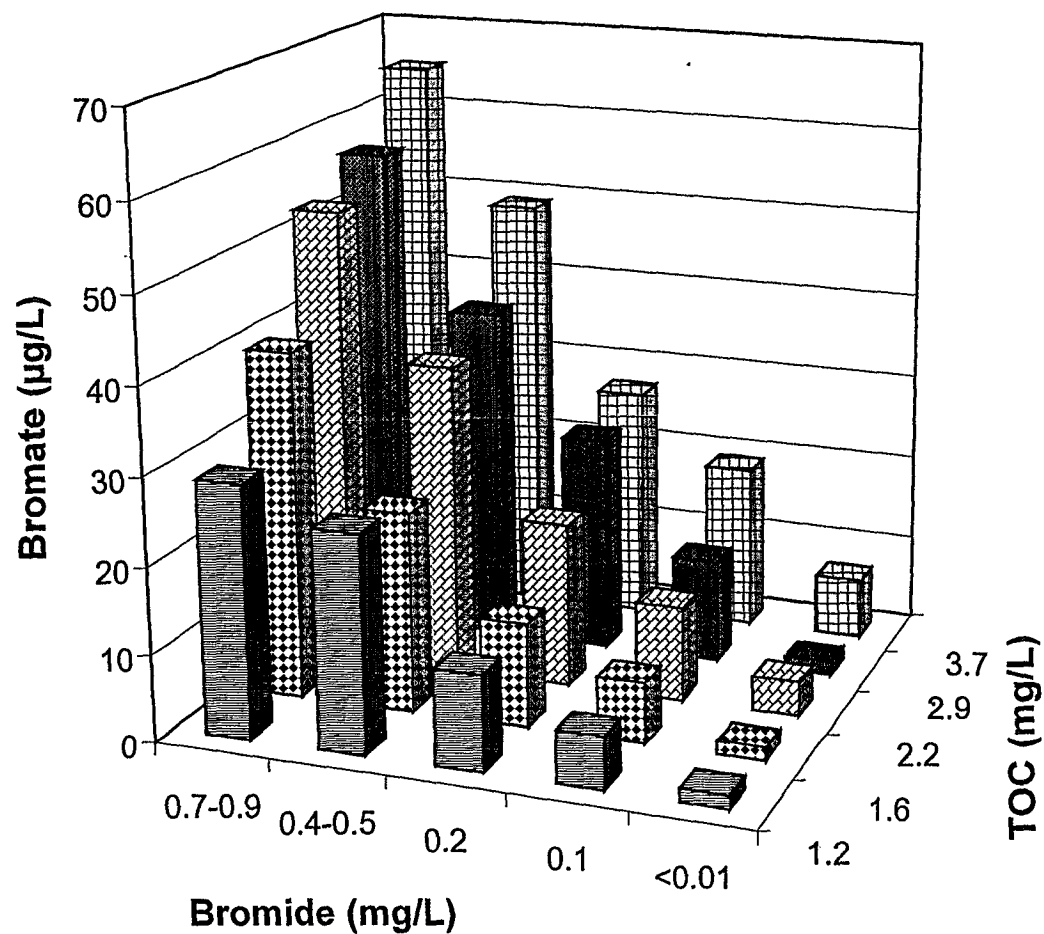


Effect of TOC on Aldoketoacid Formation (Average of 5 Bromide Tests): Ozone/TOC = 2.1 mg/mg; Ozone Residual = 0.35 mg/L
(Najm & Krasner, 1995)



**Aldo-
ketoacid**

Effect of TOC and Bromide on Bromate Formation:
Ozone/TOC = 2.1 mg/mg; Ozone Residual = 0.35 mg/L
(Najm & Krasner, 1995)

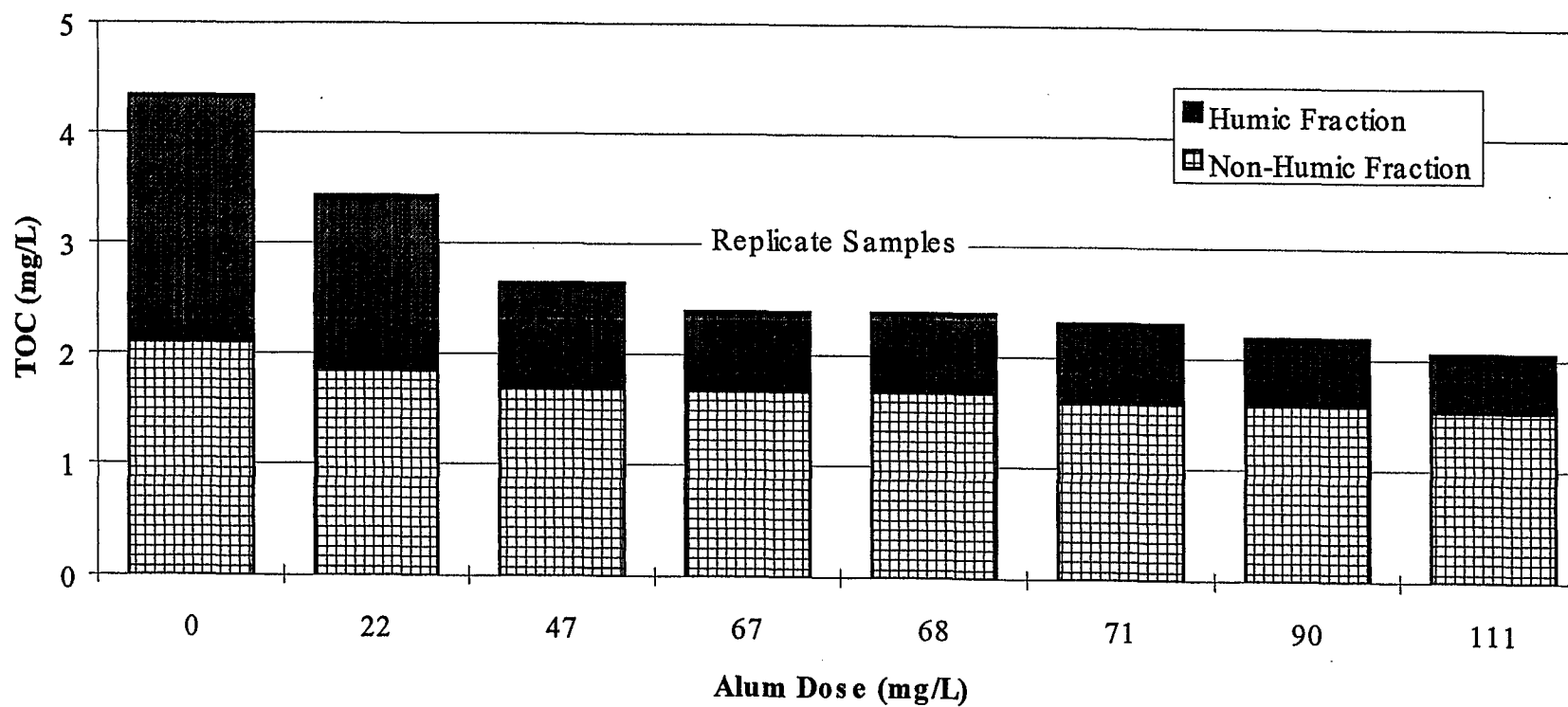


Effect of Using Different Treatment Methods on Delta Water

Effect on TOC (NOM)

Enhanced Coagulation of State Project Water (Krasner et al., 1994)

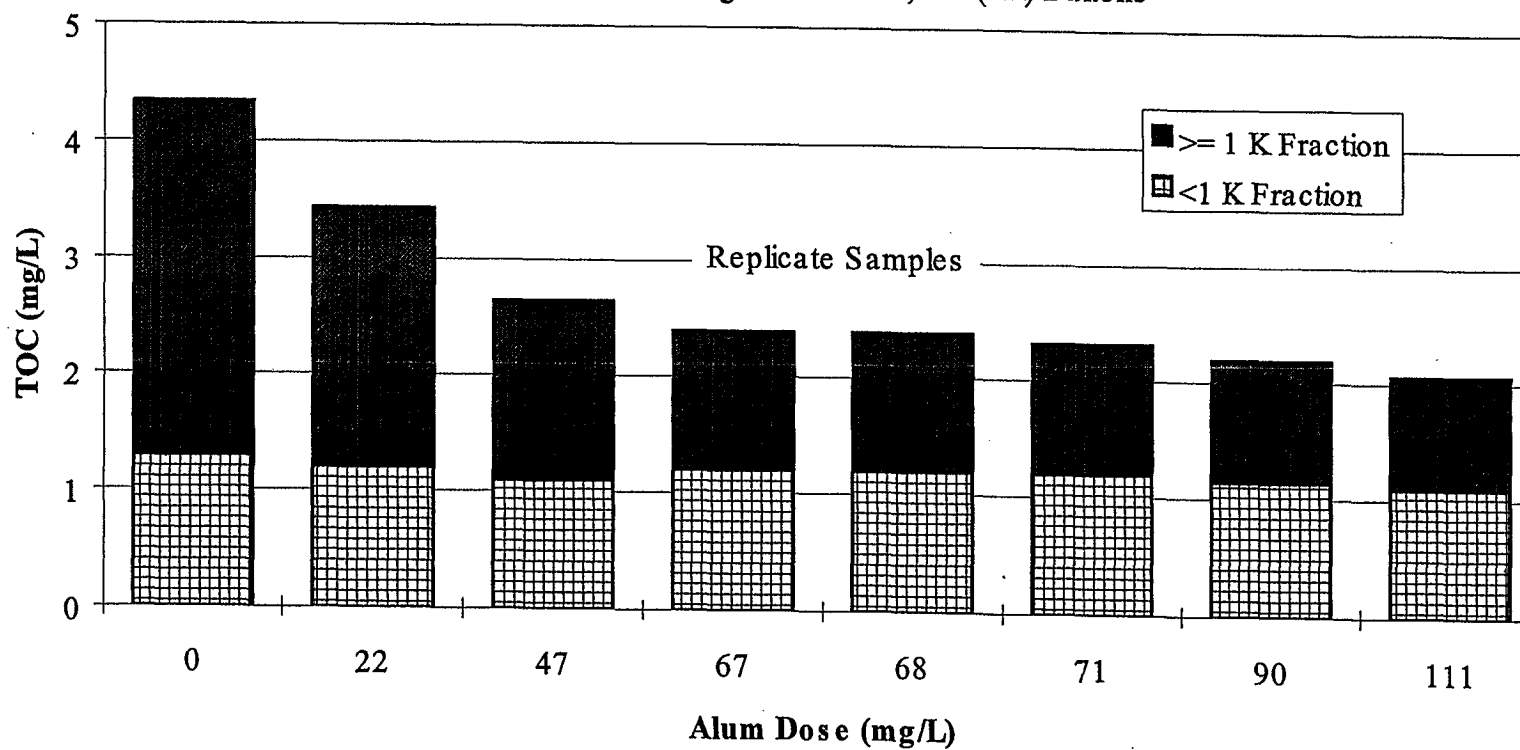
XAD-8 Resin Adsorbs Humic Fraction



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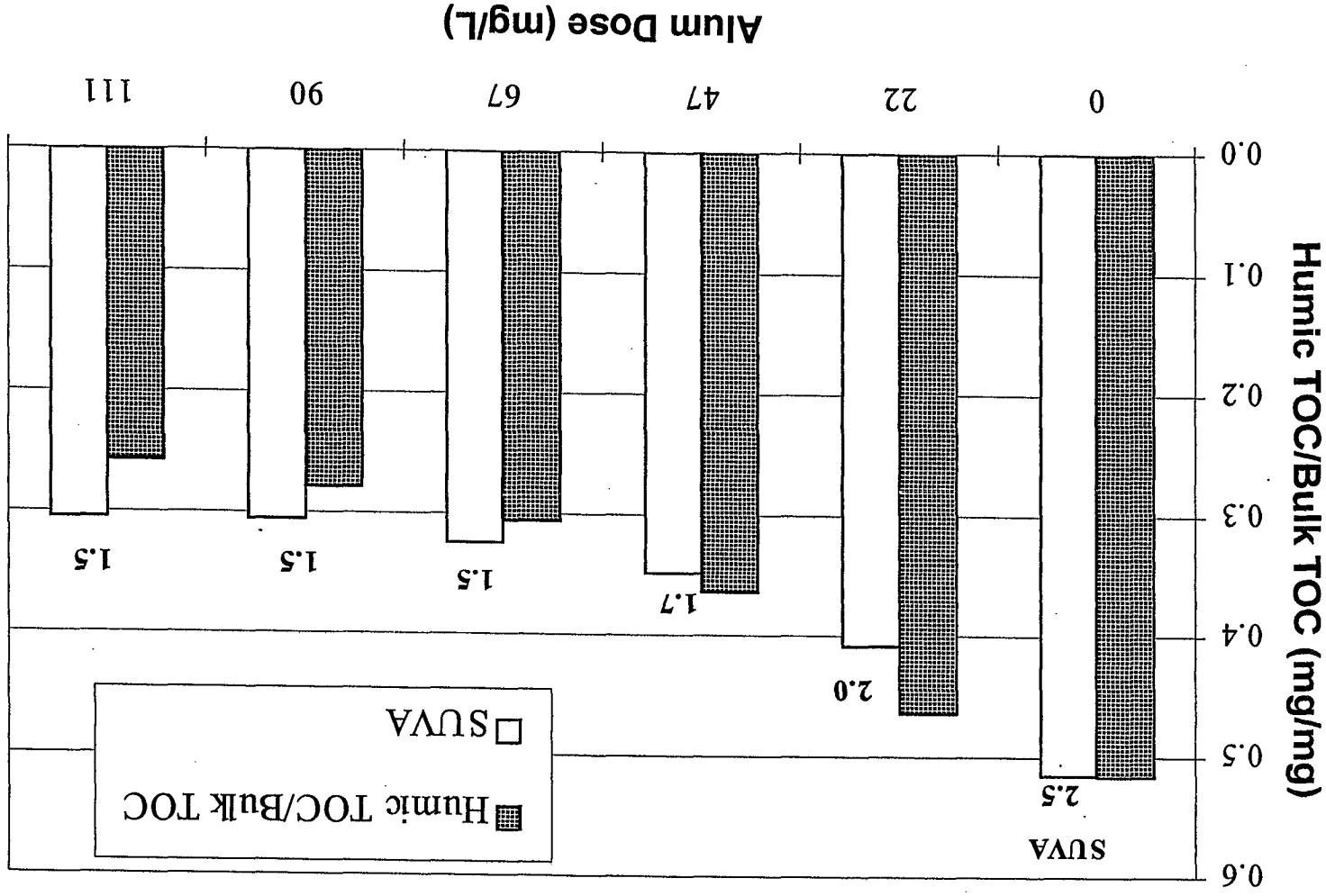
Enhanced Coagulation of State Project Water (Krasner et al., 1994)

Molecular Weight Cutoff = 1,000 (1K) Daltons

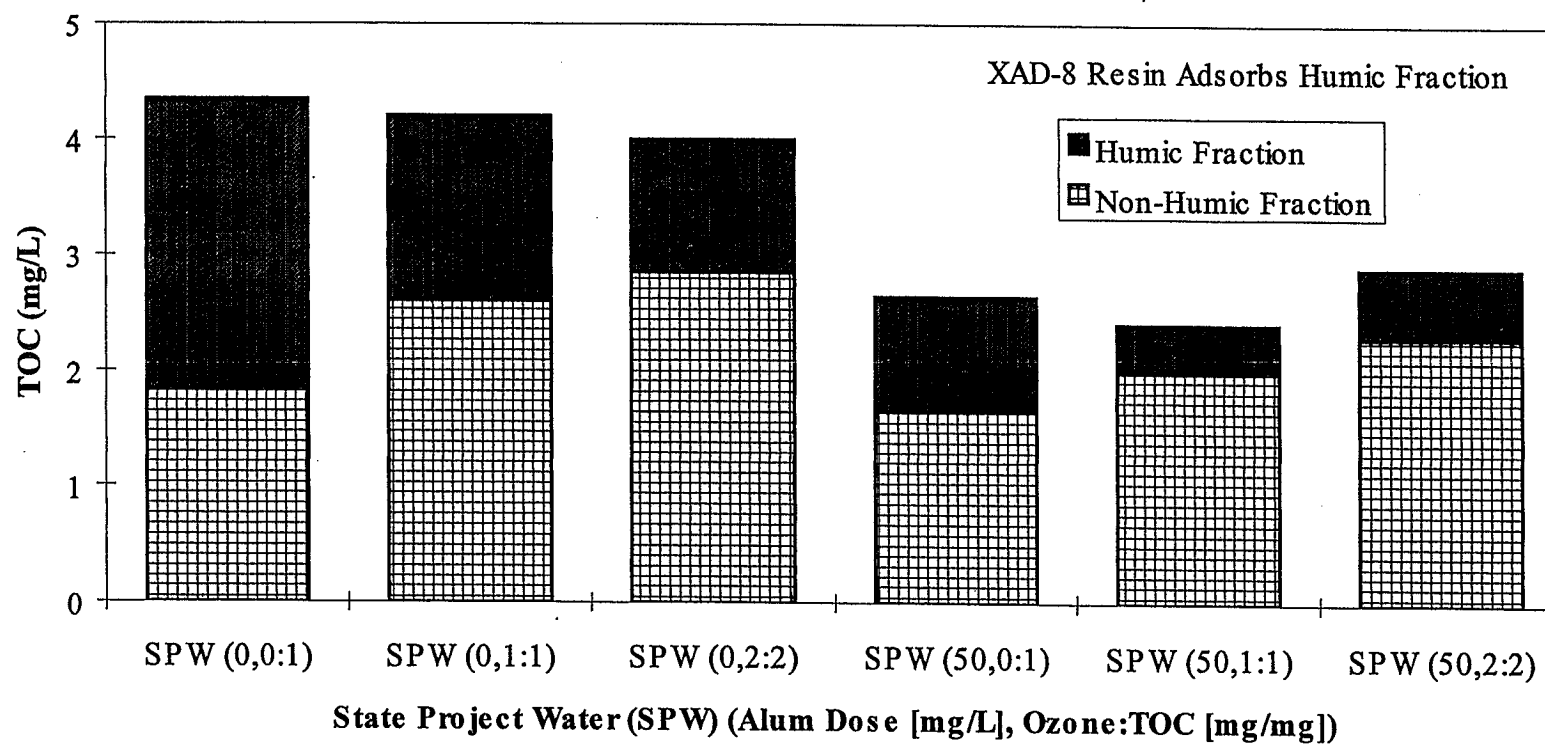


Enhanced Coagulation of State Project Water (Krasner et al., 1994)

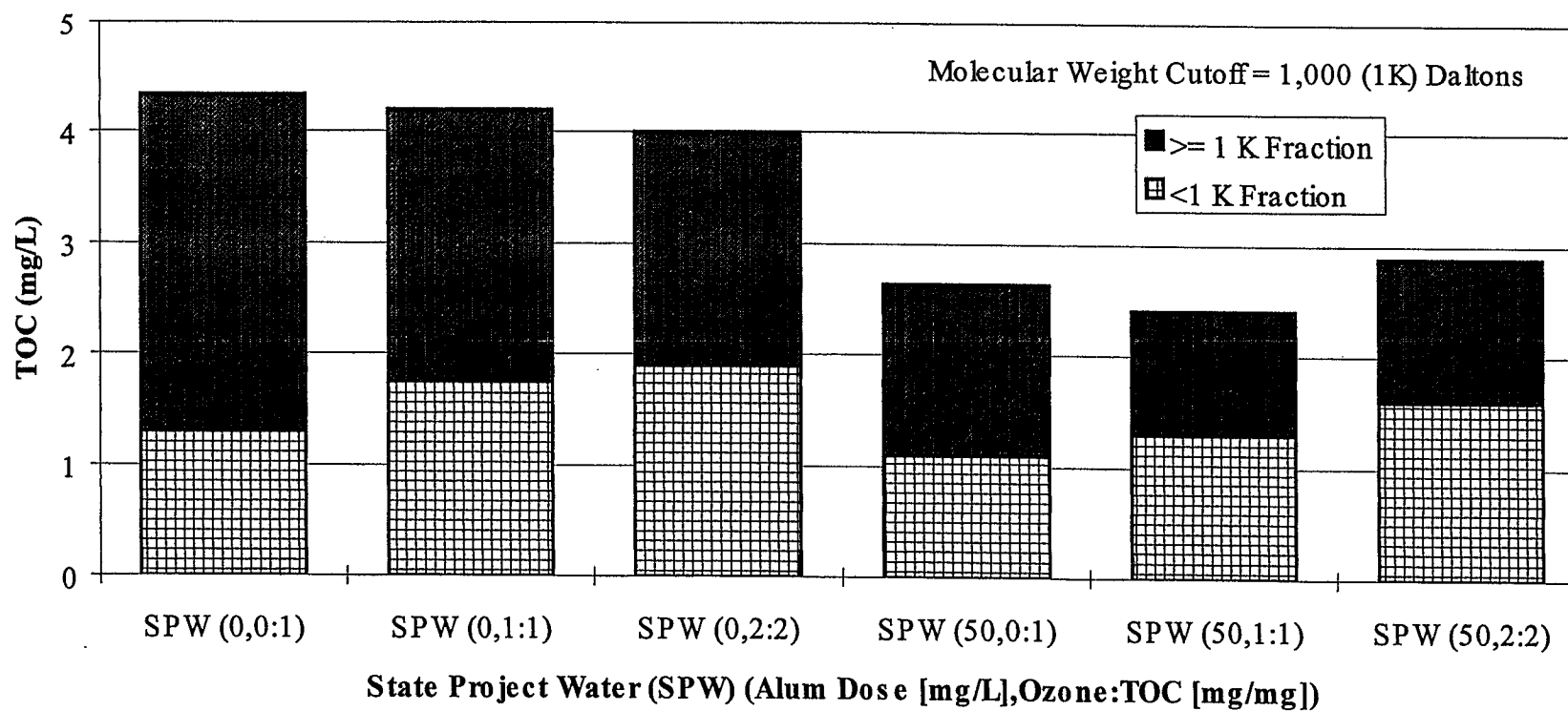
$\text{SUVA} = \text{Specific Ultraviolet Absorbance} = \text{UV} * 100 / \text{Dissolved Organic Carbon}$



Enhanced Coagulation and Ozonation of State Project Water (Krasner et al., 1994)



Enhanced Coagulation and Ozonation of State Project Water (Krasner et al., 1994)



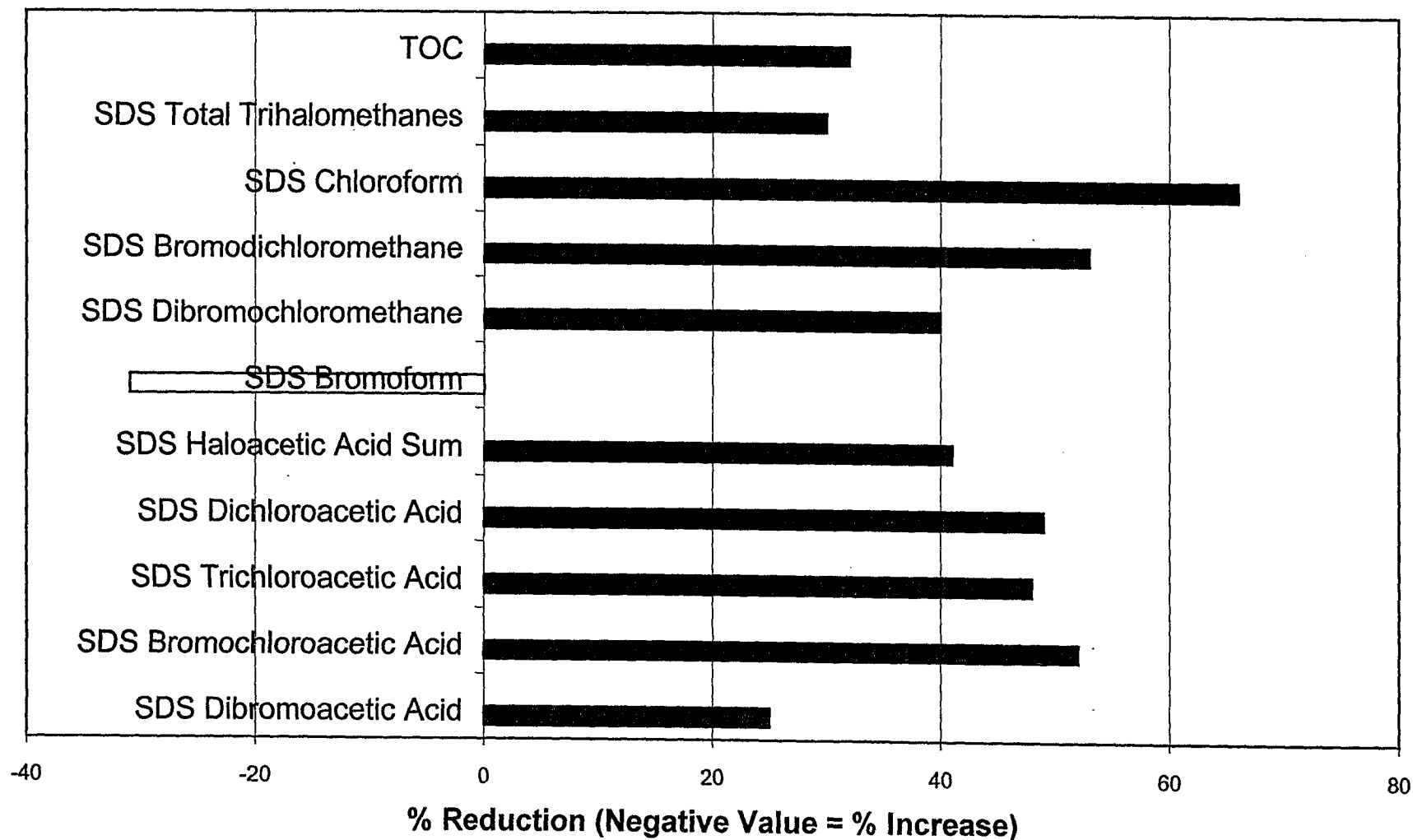
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Effect of Using Different Treatment Methods on Delta Water

Effect on DBPs

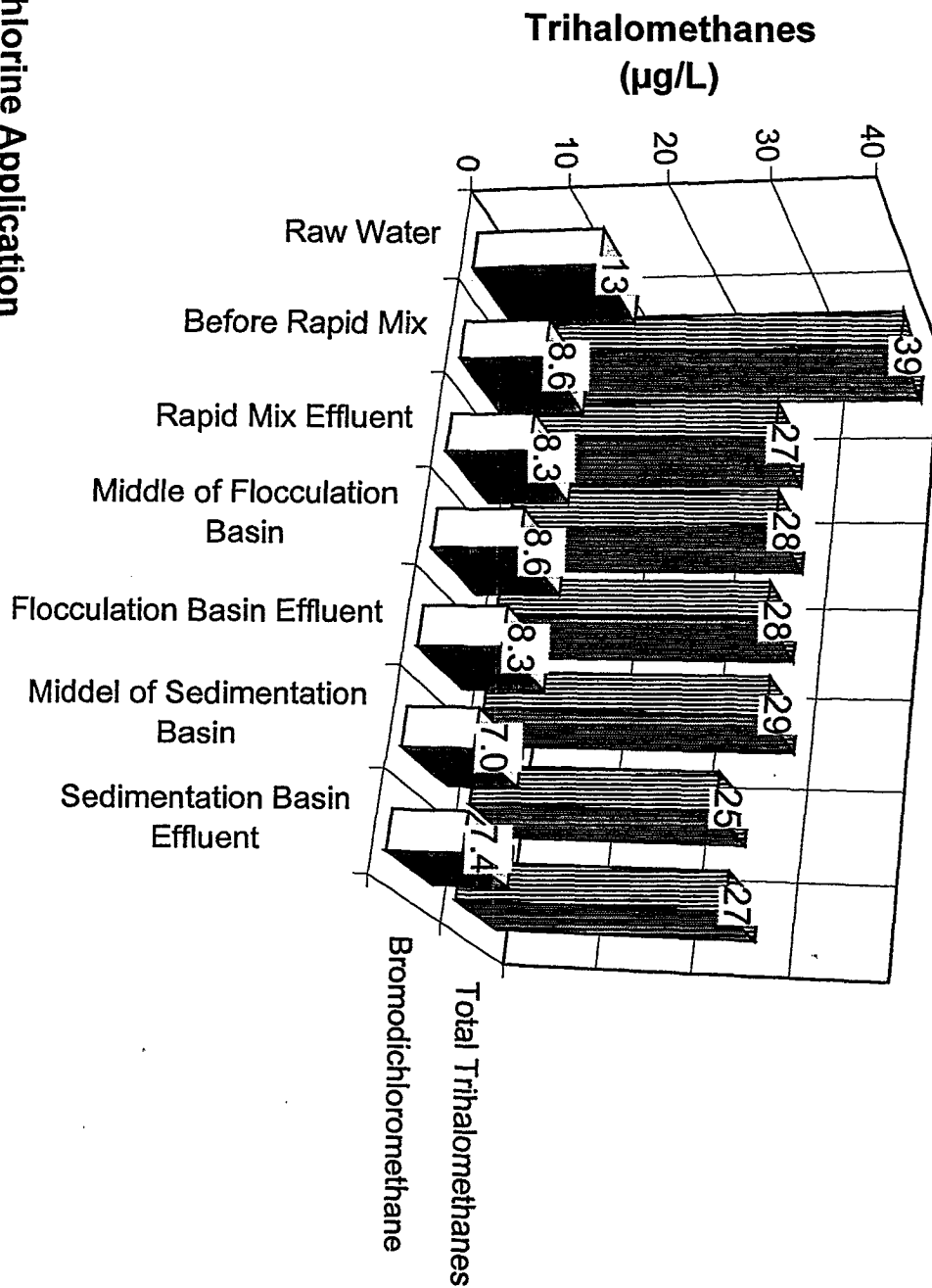
**Enhanced Coagulation of State Project Water (Cheng et al., 1995):
Coagulation Removes TOC, But Not Bromide**

SDS = Simulated Distribution System Testing



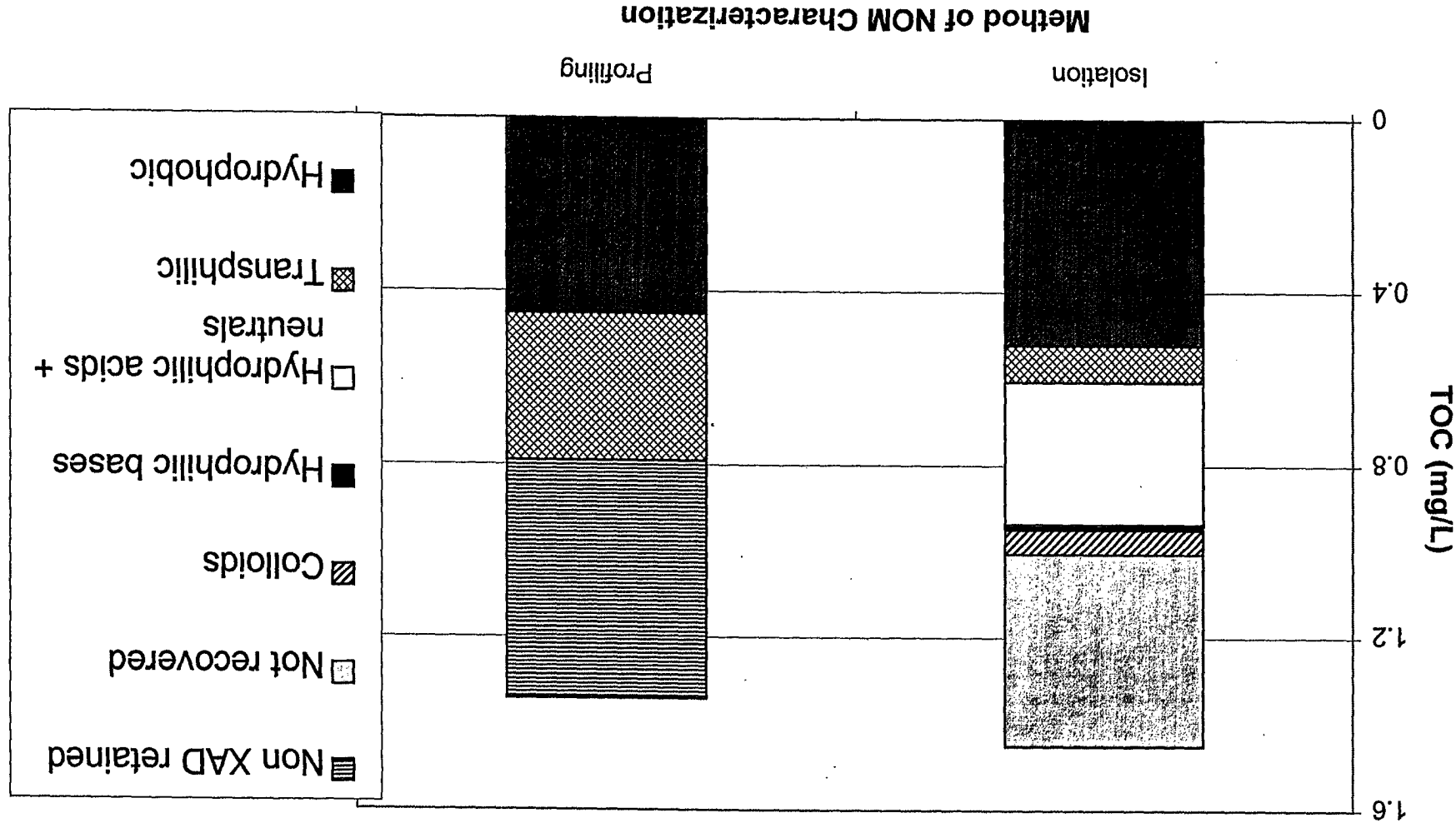
Effect of Enhanced Coagulation (~21% TOC Removal) and Moving the Point of Chlorination (3-hr Reaction Time) on DBP Formation in State Project Water (Bromide = 0.14 mg/L)

Point of Chlorine Application

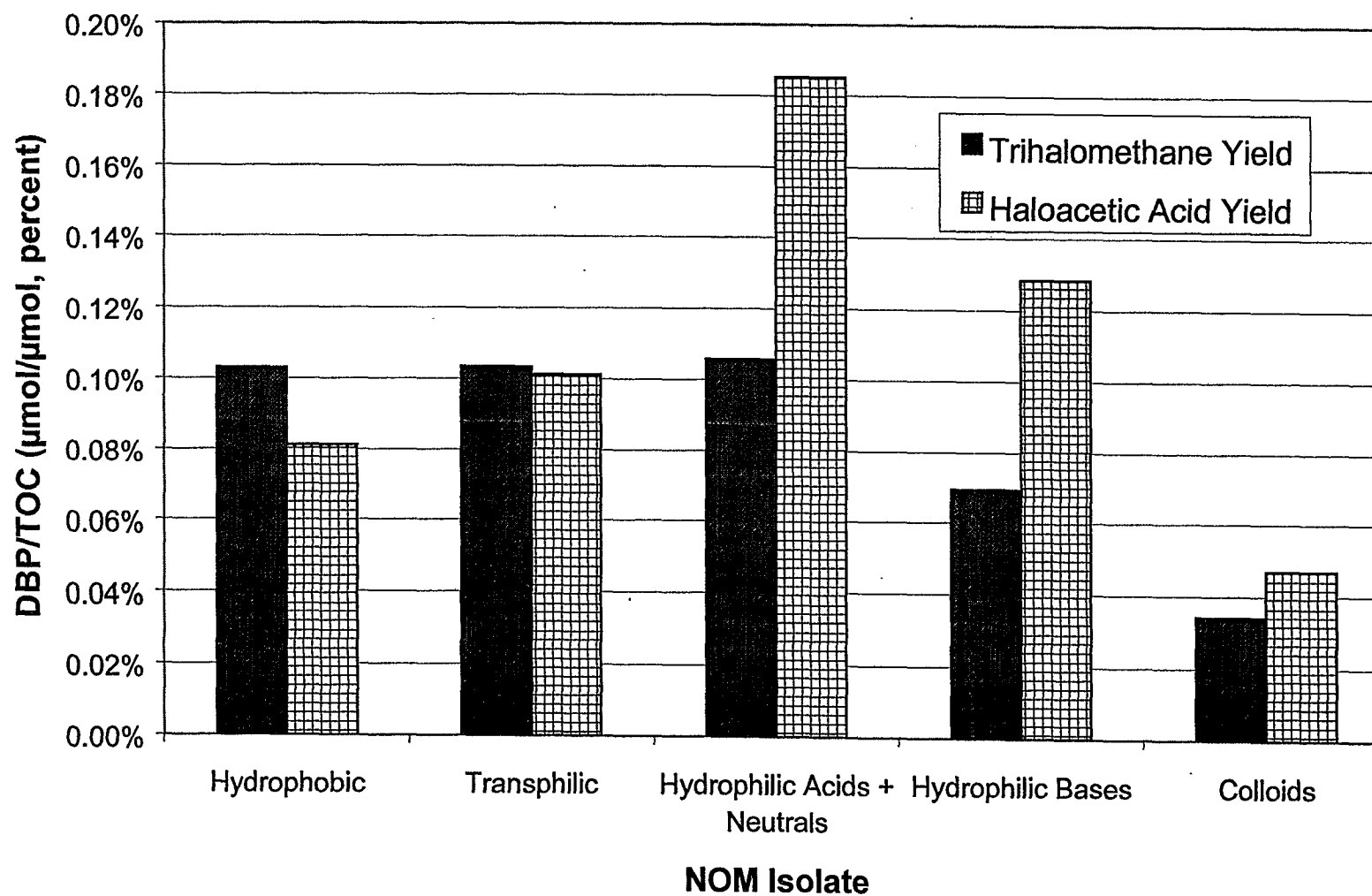


TOC Distribution of Delta Water at City of Martinez: Ozone Contactor 2 Effluent

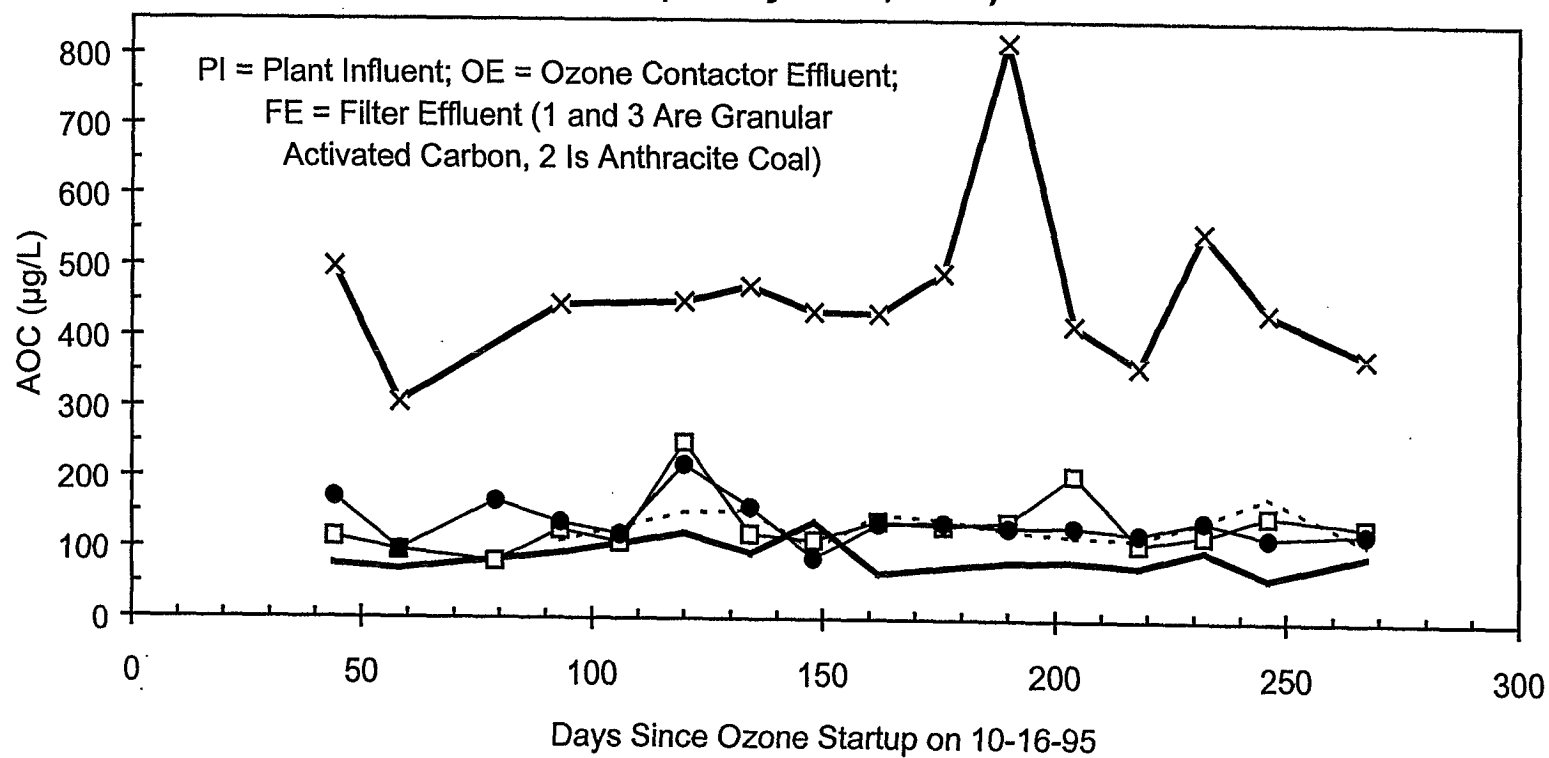
XAD-8 Resin Adsorbs Hydrophobic NOM, XAD-4 Resin Adsorbs Transphilic NOM



**DBP Yields for Delta Water at City of Martinez:
Ozone Contactor 2 Effluent NOM Isolates**



**Production and Removal of Assimilable Organic Carbon (AOC)
During Ozonation/Biofiltration of State Project Water (TOC ~3 mg/L)
(Coffey et al., 1996)**



Can Future Regulations Be Met?

Stage 2 (Stage 3) DBP Rule?

Can Future Regulations Be Met?

- Expert panel: Need TOC of 3 mg/L and bromide of 50 μ g/L (0.05 mg/L)
- Need to meet these goals at all times of year if compliance with DBP MCLs no longer allows for running annual averages
- California Department of Health Services even considered eliminating certain aspects of the running annual average for Stage 1